Anthropogenic impacts on frugivory and seed dispersal: mechanisms, scales and consequences

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Anthropogenic impacts of over-hunting and habitat fragmentation and/or degradation causes biodiversity decay worldwide. While frugivore extinctions, especially of large-bodied species, form an important component of this biodiversity loss, declines in frugivores may also lead to a concomitant seed dispersal collapse of dependent plant species in tropical and temperate ecosystems alike. Mechanisms leading to seed dispersal disruption are multiple and complex, and operate at multiple spatial and temporal scales. Apart from over-hunting, habitat loss and fragmentation may also disrupt seed dispersal even much before the extinction of dispersers. This may manifest by modifying the spatial patterns of foraging and movement of frugivorous animals. The effects of defaunation from over-hunting and habitat fragmentation may, however, emerge at smaller scales involving habitat fine structural features (e.g. the presence of individual fruiting trees), to larger scales involving species geographic ranges. The ultimate consequences of anthropogenic impact on seed dispersal also emerge at different levels of biological complexity, from the demographic responses of individual plant species, to the changes in the composition and structure of plant communities, and across the evolutionary change of plant populations.

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Pervasive consequences of overhunting in Amazonian forests: a basin-wide meta-analysis of kill profiles and implications to ecosystem structure

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I investigate nearly continental scale patterns of game vertebrate biomass across a large network of sampling sites surveyed over two decades throughout lowland Amazonia and the Guianan Shields. Macroecological patterns at different spatial scales are examined in terms of the historical and environmental determinants of habitat patch occupancy and species turnover. I first examine the extent and scale of the game vertebrate harvest across Amazonia. Patterns of frugivore abundance in structurally undisturbed forest sites are then explained in terms of key determinants of population densities, including forest type, floristic diversity, forest hydrology, rainfall seasonality, soil fertility and degree of hunting pressure. Regional scale estimates of aggregate frugivore biomass are highly variable and crucially dependent on the interaction between baseline habitat productivity and levels of offtake. On the basis of a large number of tree plots, I then estimate the consequences of persistent defaunation to forest structure and composition, and ultimately the magnitude of ecosystem services foregone by the chronic depletion of vertebrate frugivores.

Bird-mediated seed dispersal across fragmented landscapes: interactions between habitat cover and quality

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The ability of individuals to disperse through matrix habitats is a major factor behind extinction risk of species in human-impacted landscapes. For animal-dispersed plant species, dispersal success simultaneously depends on how habitat fragmentation drives both quantitative and qualitative changes in landscape structure and how these changes affect foraging behaviour of their seed-dispersal vectors. By using inverse models, we integrate these effects to explore the mechanisms by which habitat fragmentation shapes the seed dispersal kernels of *Crataegus monogyna*, in a fragmented forest of northern Spain. Our approach combined changes in both cover and fruit abundance at the immediate surround of parent plants (i.e., source effects) as well as through all environments that seeds potentially encountered along its dispersal (i.e., path effects). We found that fruit-resource was the main factor in explaining both source and path effects on seed dispersal kernels both years. Our findings imply that temporal and spatial variations in fruit availability critically condition the effects from habitat spatial configuration on frugivore decisions and therefore plant dispersal resilience in human-modified landscapes. Therefore, no consideration of the underlying resource distribution might obscure the relationship between landscape pattern and ecological processes, and subsequently our understanding about the pervasive negative effects of habitat fragmentation on biodiversity.

Pollination and seed dispersal in human-shaped landscapes

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Urbanization and agricultural intensification have destroyed and fragmented habitats causing changes in biodiversity and community composition. Consequently, modifications of ecological services such as pollination and seed dispersal might threaten isolated populations of plant species in the surviving remnants. We therefore investigated the pollinator and frugivore assemblages as well as the relative functioning of pollination and seed dispersal of rowan trees (*Sorbus aucuparia*) in forest, field margins and villages in the vicinity of Marburg, Germany. Pollinator diversity and abundance did not differ among the habitat types. Also, the proportion of flowers setting seeds was similar across the habitat types despite differences in community composition. Frugivore diversity did not differ among the habitat types. However, abundance of birds as well as the number of seeds dispersed per tree differed among the habitat types with decreasing number of visitors and dispersed seeds from forest over field margins to villages. These findings suggest a promising natural regeneration potential in human-shaped landscapes.

Changes in the frugivore assemblage reduce seed dispersal potential in fragmented Australian rainforest

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Declined frugivore abundance potentially has consequences for the dispersal and regeneration of a large number of rainforest plants. Here, we describe consequences of forest clearing and fragmentation for frugivores and seed dispersal in rainforests of subtropical Australia. First, we quantified frugivorous bird and bat abundance in forest fragments and patches of regrowth rainforest. Second, we assessed the potential of frugivore species to disperse the seeds of different rainforest plants based on dietary information. Third, we identified the plant taxa that were likely to experience substantially reduced dispersal in fragmented rainforest as a result of frugivore declines in these areas. As in other regions of the world, larger-bodied frugivore species are most disadvantaged in the fragmented forest landscape, meaning that there are fewer dispersers of large-seeded plants in these areas. There are also likely to be few dispersers of plants from certain families (e.g., Lauraceae, Myrtaceae and Rubiaceae) in fragmented rainforest. We predict reduced dispersal and altered patterns of regeneration of this significant suite of plants in rainforest fragments. However, in contrast with what has been reported for other regions, it appears that the majority of native plants retain the potential for dispersal in the study region. This may be due to high functional overlap among frugivore species, a relatively high inherent tolerance of forest fragmentation, and/or a low level of hunting in this part of the world.

Altered frugivore communities in changing landscapes- consequences for plant recruitment

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Seed dispersal by frugivores plays a key role in plant community and population dynamics, yet direct and indirect effects of habitat and landscape changes on the recruitment of animal-dispersed plants remain poorly known. We examined if, and to what extent, recruitment at early life-stages of a bird-dispersed tree differs between and within forest fragments varying in size, surrounding matrix and microhabitats. Three years of field experiments revealed that patterns of seed germination and seedling survival were largely inconsistent, both in space and time. However, two clear patterns emerged from this study. First, performance of seeds and seedlings was consistently better away from than under conspecific fruiting trees. This indirectly translates into reduced recruitment in heavily disturbed fragments, where most seeds remain undispersed due to the loss of key disperser species. Second, exotic plantations bordering indigenous forest fragments may provide suitable conditions for native tree recruitment. Individual based modelling predicts a 90% recruitment increase in tiny forest remnants buffered by exotic plantations compared to those surrounded by farmland, this nursing effect being less effective under dryer conditions. We conclude that habitat changes affect frugivorous seed dispersal and plant recruitment in complex and context-dependent ways, having important implications for on-site habitat management in view of current global change.

Megafaunal losses: when does a forest become empty?

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Animal seed dispersal is a key ecological process that maintains forest diversity and ecosystem function by shaping the distribution and regeneration of plant species. In particular, large vertebrates are important long distance seed dispersers of large-seeded plants due to their large home ranges and long gut retention times. Unfortunately, increased hunting pressure and habitat loss are seriously threatening these animals and their role in the ecosystem. Thus, it is necessary to understand whether “empty forests” can sustain their species diversity in the long term. In this study, we explore the possibility that forests become functionally “empty” before megafauna species are lost due to the disruption of ecological processes such as long distance seed dispersal. Our study focuses on the interaction between the Baird’s tapir (Tapirus bairdii), the largest neotropical terrestrial mammal, and the large-seeded plant species, Manilkara zapota (zapote). We hypothesized that a disruption in the long distance seed dispersal by tapirs can cause a decrease in their effectiveness as seed dispersers, triggering a cascade of ecological effects. We extend our observations to other megafauna-large seeded plant interactions and suggest that forested areas where megafauna species are still present might become ‘empty’ if key elements of seed dispersal are lost. Future research on long-distance seed dispersal by megafauna is necessary to prevent the loss of functional ecosystems.

Defaunation drives rapid evolutionary shrinkage of seeds

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Large frugivorous birds, such as toucans, are important seed dispersers of large seeds in neotropical ecosystems. We present evidence demonstrating that seed size of the palm *Euterpe edulis* has been reduced in forests where these birds are rare or extinct due to poaching or fragmentation. We argue that similar evolutionary changes in seed size may be underway worldwide, since large frugivores are the first to disappear in the current extinction.